Derivation of Empirical Laws for the

Mass of Sub-Atomic Baryonic Particles.

[1]

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ABSTRACT.

The purpose of this paper is the derivation of empirical laws for the mass of sub-atomic Baryonic particles. The basis for development is the sum of the masses of their constituent quarks. Particles with intrinsic angular momentum of $J = 1/2\,\hbar$ and $3/2\,\hbar$ are covered.

CONTENTS.

1.0 Introduction.

There are two major references for these particles, Wikipedia, [1], and The Particle Data Group, (PDG), [2]. The second of these contains the more extensive data, but it is the first that will primarily be used in this paper, because it makes reference to a majority of the sub-atomic particles to be considered These are listed with all pertinent details in Appendix A.

For particles with intrinsic angular momentum $J = 1/2\,\hbar$, there are a total of 40 recorded. All are made up of combinations of three out of five of the six known quarks, (Up, Down, Strange, Charm and Bottom). Of these 40, the mass of 16 are currently recorded as unknown.

For particles with intrinsic angular momentum $J = 3/2\,\hbar$, there are a total of 35 recorded. These include the resonance variants of 30 of the above, together with 5 extra comprising three identical quarks. Of these 35, the mass of 16 are currently recorded as unknown

2.0 Development of an Empirical Law for the Mass of Baryonic Particles with Intrinsic Angular Momentum $J = 1/2\,\hbar$.

2.1 Accuracy of the Source Data in the Derivation.

All masses will be quoted in units of MeV/c^2. The accuracy of the derivation will depend upon two factors, (i) the accuracy with which the masses are quoted in [1], and (ii) the accuracy with which the masses of the constituent quarks are "known". Of these two the second is the more uncertain and therefore all derived numbers will only be quoted to two decimal places.
Note that only particle mass is considered here, particle and quark electric charges are not a factor in the development.

2.2 The Masses of the Constituent Quarks.

In all literature, both referenced and otherwise, the mass of all quarks is quoted as being within a range of values. These quoted ranges do not in general agree, but differ slightly. The range chosen, together with the average value, for use here, is shown in the following table.

Quark	Mass Range, MeV/c^2	Average Value, MeV/c^2
u	1.5 to 3.3	2.4
d	3.5 to 6.0	4.75
s	70 to 130	100
c	1160 to 1340	1250
b	4230 to 4370	4300

Table 2.1 - Average Quark Masses.

2.3 The Mass Law for Particles of Intrinsic Angular Momentum $J = 1/2\,\hbar$.

Of the 24 particles to be used to derive this law, (i.e. 40 less the 16 unknowns), there are 6 that are also omitted because they are special cases, in that they are variants of other particles that have the same quark content, but which in addition have a higher total mass. This is illustrated in the following table.

Particle	Quark Content	Mass MeV/c^2	Variant	Mass MeV/c^2
Λ^0	uds	1115.68	Σ^0	1192.64
Λ_c^+	udc	2286.46	Σ_c^+	2452.90
Ξ_c^+	usc	2467.80	$\Xi_c^{/+}$	2575.60
Ξ_c^0	dsc	2470.89	$\Xi_c^{/0}$	2577.80
Ξ_b^0	usb	5787.80	$\Xi_b^{/0}$	Unknown
Ξ_b^-	dsb	5791.12	$\Xi_b^{/-}$	Unknown

Table 2,2 - J = 1/2 $\hbar$ Particle Variants.

These particles and their variants are further discussed in Section 3.0 below.

The relevant details of the remaining particles to be used to derive this law are therefore as shown in Table 2.3 below.

Appendix A Item Number	Particle		Mass, (MeV/c^2)			
	Name	Symbol	Particle	Σ(Quark Content)	Ln (Quark Mass)	Ln (Particle Mass)
1	Proton	p^+	938.27	9.55	2.256541154	6.844039886
2	Neutron	n^0	939.57	11.90	2.476538400	6.845417002
7	Sigma	Σ^+	1,189.37	104.80	4.652053772	7.081179034
9	Sigma	Σ^0	1,192.64	107.15	4.674229722	7.083924616
10	Sigma	Σ^-	1,197.45	109.50	4.695924549	7.087949575
17	Xi	Ξ^0	1,314.86	202.40	5.310245937	7.181485475
18	Xi	Ξ^-	1,321.71	204.75	5.321789723	7.186681632
12	c Sigma	Σ^+_c	2,452.90	1,257.15	7.136602533	7.805026277
13	c Sigma	Σ^0_c	2,453.74	1,259.50	7.138470096	7.805368670
11	c Sigma	Σ^{++}_c	2,453.98	1,254.80	7.134731476	7.805466475
21	c Prime Xi	$\Xi^{/+}_c$	2,575.60	1,352.40	7.209636071	7.853837796
22	c Prime Xi	$\Xi^{/0}_c$	2,577.90	1,354.75	7.211372214	7.854730393
36	c Omega	Ω^0_c	2,695.20	1,450.00	7.279318835	7.899227692
24	cc Xi	Ξ^+_{cc}	3,518.90	2,504.75	7.825944208	8.165903720
6	b Lambda	Λ^0_b	5,619.40	4,307.15	8.368031711	8.633980176
14	b Sigma	Σ^+_b	5,811.30	4,304.80	8.367485958	8.667559577
16	b Sigma	Σ^-_b	5,815.50	4,309.50	8.368577167	8.668282046
37	b Omega	Ω^-_b	6,071.00	4,500.00	8.411832676	8.711278615

Table 2.3 - Particle Data Used to Derive the Mass Law for Particles with J = 1/2 $\hbar$.

The data in the two final RH columns, {Ln(Quark Mass) and Ln(Particle mass)}, is now plotted and shown in Appendix B.1. Curve fitting this plot provides the following empirical law

$$m_p = EXP\left[\frac{6.816538 - 0.4565Ln\{\Sigma(m_q)\}}{1 - 0.06465Ln\{\Sigma(m_q)\} - 0.00161Ln\{\Sigma(m_q)\}^2}\right] \qquad (2.1)$$

where m_p is the mass of the particle in question.

$\Sigma(m_q)$ is the mass of its constituent quarks.

Eq.(2.1) is now used to determine the masses of those particles which are recorded in [1] and Appendix A as unknown. The results are shown in the following table, (Figures in red are the calculated numbers).

Appendix A Item Number	Particle		Mass, (MeV/c^2)					
	Name	Symbol	Particle	Quark Content	Ln (Quark Mass)	Ln (Particle Mass)	Calculated Mass of Unknowns	
23	cc Xi	Ξ^{++}_{cc}	Unknown	2,502.40	7.825005550	8.202682506	**3,650.73**	These Values are Calculated from the "Mass Law" of Eq.(2.1).
38	cc Omega	Ω^{+}_{cc}	Unknown	2,600.00	7.863266724	8.230101893	**3,752.22**	
15	b Sigma	Σ^{0}_{b}	Unknown	4,307.15	8.368031711	8.653788228	**5,731.82**	
28	bXi	$\Xi^{/0}_{b}$	Unknown	4,402.40	8.389905126	8.675165110	**5,855.67**	
29	bXi	$\Xi^{/-}_{b}$	Unknown	4,404.75	8.390438783	8.675690249	**5,858.74**	
32	cb Xi	Ξ^{+}_{cb}	Unknown	5,552.40	8.621985546	8.920938300	**7,487.11**	
34	cb Prime Xi	$\Xi^{/+}_{cb}$	Unknown	5,552.40	8.621985546	8.920938300	**7,487.11**	
33	cb Xi	Ξ^{0}_{cb}	Unknown	5,554.75	8.622408697	8.921420495	**7,490.72**	
35	cb Prime Xi	$\Xi^{/0}_{cb}$	Unknown	5,554.75	8.622408697	8.921420495	**7,490.72**	
39	cb Omega	Ω^{0}_{cb}	Unknown	5,650.00	8.639410824	8.940905378	**7,638.11**	
40	cb Prime Omega	$\Omega^{/0}_{cb}$	Unknown	5,650.00	8.639410824	8.940905378	**7,638.11**	
42	ccb Omega	Ω^{+}_{ccb}	Unknown	6,800.00	8.824677891	9.168096867	**9,586.36**	
30	bb Xi	Ξ^{0}_{bb}	Unknown	8,602.40	9.059796513	9.501608030	**13,381.23**	
31	bb Xi	Ξ^{-}_{bb}	Unknown	8,604.74	9.060068493	9.502027381	**13,386.84**	
41	bb Omega	Ω^{-}_{bb}	Unknown	8,700.00	9.071078305	9.519073477	**13,616.99**	
43	cbb Omega	Ω^{0}_{cbb}	Unknown	9,850.00	9.195226734	9.721311399	**16,669.09**	

Table 2.4 - Determination of the Mass, from the Mass Law, of Those Particles Recorded as Unknown, (J = 1/2 $\hbar$).

From Tables 2.3 and 2.4 a composite plot for all 34 particles can now be produced. This is shown in Appendix B.2.

2.4 The Mass Law for Particles of Intrinsic Angular Momentum J = 3/2 $\hbar$.

The same process as above can be used to determine an empirical law for particles with J = 3/2 $\hbar$. The relevant data for particles used in the derivation is shown in the following table.

Appendix A Item Number	Particle		Mass, (MeV/c^2)			
	Name	Symbol	Particle	Σ(Quark Content)	Ln (Quark Mass)	Ln (Particle Mass)
44	Delta	Δ^{++}	1,232.00	7.20	1.974081026	7.116394144
45	Delta	Δ^{+}	1,232.00	9.55	2.256541154	7.116394144
47	Delta	Δ^{0}	1,232.00	11.90	2.476538400	7.116394144
49	Delta	Δ^{-}	1,232.00	14.25	2.656756907	7.116394144
50	* Sigma	Σ^{*+}	1,382.80	104.80	4.652053772	7.231865708
53	* Sigma	Σ^{*0}	1,383.70	107.15	4.674229722	7.23251635
56	* Sigma	Σ^{*-}	1,387.20	109.50	4.695924549	7.235042606
65	* Xi	Ξ^{*0}	1,531.80	202.40	5.310245937	7.334198793
67	* Xi	Ξ^{*-}	1,535.00	204.75	5.321789723	7.33628566
79	Omega	Ω^{-}	1,672.45	300.00	5.703782475	7.422044896
59	c * Sigma	Σ^{*++}_{c}	2,518.00	1,254.80	7.134731476	7.831220215
60	c * Sigma	Σ^{*+}_{c}	2,517.50	1,257.15	7.136602533	7.843900111
61	c * Sigma	Σ^{*0}_{c}	2,518.80	1,259.50	7.138470096	7.831537877
69	c * Xi	Ξ^{*+}_{c}	2,645.90	1,352.40	7.209636071	7.880766551
70	c * Xi	Ξ^{*0}_{c}	2,649.25	1,354.75	7.211372214	7.88203186
82	c Omega	Ω^{*0}_{c}	2,765.90	1,450.00	7.279318835	7.925121358
62	b * Sigma	Σ^{*+}_{b}	5,832.10	4,304.80	8.367485958	8.67113242
64	b * Sigma	Σ^{*-}_{b}	5,835.10	4,309.50	8.368577167	8.671646683
73	b * Xi	Ξ^{*0}_{b}	5,945.50	4,402.40	8.389905126	8.69038991

Table 2.5 - Particle Data Used to Derive the Mass Law for Particles with $J = 3/2\,\hbar$.

The data in the final two RH columns is again plotted and shown in Appendix C.1. Curve fitting this plot produces the following empirical law

$$m_p = EXP\left[\frac{7.180914 - 0.52679 Ln\{\Sigma(m_q)\}}{1 - 0.0658 Ln\{\Sigma(m_q)\} - 0.00185 Ln\{\Sigma(m_q)\}^2}\right] \tag{2.2}$$

Eq.(2.2) is now used to determine the masses of those particles which are recorded in [1] and Appendix A as unknown. The results are shown in the following table, (Figures in red are the calculated numbers).

Appendix A Item Number	Particle		Mass, (MeV/c^2)					
	Name	Symbol	Particle	Quark Content	Ln (Quark Mass)	Ln (Particle Mass)	Calculated Mass of Unknowns	
71	cc * Xi	Ξ^{*++}_{cc}	Unknown	2,502.40	7.825005550	8.226111437	**3,737.27**	These Values are Calculated from the "Mass Law" of Eq.(2.2).
72	cc * Xi	Ξ^{*+}_{cc}	Unknown	2,504.75	7.825944208	8.226749421	**3,739.66**	
84	cc Omega	Ω^{*+}_{cc}	Unknown	2,600.00	7.863266724	8.252425642	**3,836.92**	
87	cccOmega	Ω^{++}_{ccc}	Unknown	3750.00	8.229511119	8.540301423	**5,116.89**	
63	b * Sigma	Σ^{*0}_{b}	unknown	4,307.15	8.368031711	8.669101847	**5,820.27**	
74	b * Xi	Ξ^{*-}_{b}	unknown	4,404.75	8.390438783	8.691137649	**5,949.95**	
83	b Omega	Ω^{*-}_{b}	unknown	4,500.00	8.411832676	8.712507581	**6,078.47**	
77	cb* Xi	Ξ^{*+}_{cb}	unknown	5,552.40	8.621985546	8.941101674	**7,639.61**	
78	cb* Xi	Ξ^{*0}_{cb}	unknown	5,554.75	8.622408697	8.941598913	**7,643.41**	
85	cb Omega	Ω^{*0}_{cb}	unknown	5,650.00	8.639410824	8.961710544	**7,798.69**	
88	ccb Omega	Ω^{*+}_{ccb}	Unknown	6,800.00	8.824677891	9.198911672	**9,886.36**	
75	bb* Xi	Ξ^{*0}_{bb}	Unknown	8,602.40	9.059796513	9.556095552	**14,130.57**	
76	bb* Xi	Ξ^{*-}_{bb}	Unknown	8,604.75	9.060069655	9.556553341	**14,137.04**	
86	bb Omega	Ω^{*-}_{bb}	Unknown	8,700.00	9.071078305	9.575095104	**14,401.61**	
89	cbb Omega	Ω^{*0}_{cbb}	Unknown	9,850.00	9.195226734	9.797240652	**17,984.05**	
90	bbbOmega	Ω^{-}_{bbb}	Unknown	12900.00	9.464982590	10.37902937	**32,177.71**	

Table 2.6 - Determination of the Mass, from the Mass Law, of Those Particles Recorded as Unknown, (J = 3/2 $\hbar$).

From Tables 2.5 and 2.6 a composite plot for all 35 particles can now be produced. This is shown in Appendix C.2.

2.5 Accuracy of the Results.

To determine the accuracy with which this process has been effected, a composite table of all results has been constructed and percentage accuracy calculated. This table is shown below.

Particle	Final Mass Laws, (Primed and Lamda Particles Omitted), J = 1/2 hBar				Particle	Final Mass Laws, J = 3/2 hBar			Calculated Mass Accuracy
	Σ(Quark Mass)	Recorded Mass	Calculated Mass	Calculated Mass Accuracy		Σ(Quark Mass)	Recorded Mass	Calculated Mass	
p^+	9.55	938.27	934.88	-0.3610%	Δ^{++}	7.2	1,232.00	1232.40	0.0324%
n^0	11.90	939.57	944.31	0.5053%	Δ^{+}	9.55	1,232.00	1231.24	-0.0618%
Σ^+	104.80	1,189.37	1168.31	-1.7710%	Δ^{0}	11.90	1,232.00	1232.46	0.0377%
Σ^0	107.15	1,192.64	1172.47	-1.6916%	Δ^{-}	14.25	1,232.00	1234.95	0.2394%
Σ^-	109.50	1,197.45	1176.59	-1.7420%	Σ^{*+}	104.80	1,382.80	1386.29	0.2521%
Ξ^0	202.40	1,314.86	1320.08	0.3969%	Σ^{*0}	107.15	1,383.70	1389.78	0.4395%
Ξ^-	204.75	1,321.71	1323.35	0.1244%	Σ^{*-}	109.50	1,387.20	1393.26	0.4366%
Σ^+_c	1,257.15	2,452.90	2424.87	-1.1429%	Ξ^{*0}	202.40	1,531.80	1518.07	-0.8964%
Σ^0_c	1,259.50	2,453.74	2427.11	-1.0852%	Ξ^{*-}	204.75	1,535.00	1520.98	-0.9131%
Σ^{++}_c	1,254.80	2,453.98	2422.62	-1.2780%	Ω^-	300.00	1,672.45	1632.75	-2.3738%
$\Xi^{+/}_c$	1,352.40	2,575.60	2515.97	-2.3152%	Σ^{*++}_c	1,254.80	2,518.00	2547.98	1.1908%
$\Xi^{0/}_c$	1,354.75	2,577.90	2518.22	-2.3151%	Σ^{*+}_c	1,257.15	2,517.50	2550.13	1.2962%
Ω^0_c	1,450.00	2,695.20	2609.41	-3.1829%	Σ^{*0}_c	1,259.50	2,518.80	2552.28	1.3291%
Ξ^+_{cc}	2,504.75	3,518.90	3653.16	3.8154%	Ξ^{*+}_c	1,352.40	2,645.90	2637.25	-0.3270%
Λ^0_b	4,307.15	5,619.40	5731.82	2.0006%	Ξ^{*0}_c	1,354.75	2,649.25	2639.40	-0.3718%
Σ^+_b	4,304.80	5,811.30	5728.78	-1.4199%	Ω^{*0}_c	1,450.00	2,765.90	2726.80	-1.4137%
Σ^-_b	4,309.50	5,815.50	5734.86	-1.3867%	Ξ^{*++}_{cc}	2,502.40	Unknown	3737.27	N/A
Ω^-_b	4,500.00	6,071.00	5984.25	-1.4290%	Ξ^{*+}_{cc}	2,504.75	Unknown	3739.66	N/A
Ξ^{++}_{cc}	2,502.40	Unknown	3650.73	N/A	Ω^{*+}_{cc}	2,600.00	Unknown	3836.92	N/A
Ω^+_{cc}	2,600.00	Unknown	3752.22	N/A	Ω^{++}_{ccc}	3750.00	Unknown	5116.89	N/A
Σ^0_b	4,307.15	Unknown	5731.82	N/A	Σ^{*+}_b	4,304.80	5,832.10	5817.17	-0.2560%
$\Xi^{0/}_b$	4,402.40	Unknown	5855.67	N/A	Σ^{*0}_b	4,307.15	Unknown	5820.27	N/A
$\Xi^{-/}_b$	4,404.75	Unknown	5858.74	N/A	Σ^{*-}_b	4,309.50	5,835.10	5823.37	-0.2011%
Ξ^+_{cb}	5,552.40	Unknown	7487.11	N/A	Ξ^{*0}_b	4,402.40	5,945.50	5946.80	0.0219%
$\Xi^{+/}_{cb}$	5,552.40	Unknown	7487.11	N/A	Ξ^{*-}_b	4,404.75	Unknown	5949.95	N/A
Ξ^0_{cb}	5,554.75	Unknown	7490.72	N/A	Ω^{*-}_b	4,500.00	Unknown	6078.47	N/A
$\Xi^{0/}_{cb}$	5,554.75	Unknown	7490.72	N/A	Ξ^{*+}_{cb}	5,552.40	Unknown	7639.61	N/A
Ω^0_{cb}	5,650.00	Unknown	7638.11	N/A	Ξ^{*0}_{cb}	5,554.75	Unknown	7643.41	N/A
$\Omega^{0/}_{cb}$	5,650.00	Unknown	7638.11	N/A	Ω^{*0}_{cb}	5,650.00	Unknown	7798.69	N/A
Ω^+_{ccb}	6,800.00	Unknown	9586.36	N/A	Ω^{*+}_{ccb}	6,800.00	Unknown	9886.36	N/A
Ξ^0_{bb}	8,602.40	Unknown	13381.23	N/A	Ξ^{*0}_{bb}	8,602.40	Unknown	14130.57	N/A
Ξ^-_{bb}	8,604.74	Unknown	13386.84	N/A	Ξ^{*-}_{bb}	8,604.75	Unknown	14137.04	N/A
Ω^-_{bb}	8,700.00	Unknown	13616.99	N/A	Ω^{*-}_{bb}	8,700.00	Unknown	14401.61	N/A
Ω^0_{cbb}	9,850.00	Unknown	16669.09	N/A	Ω^{*0}_{cbb}	9,850.00	Unknown	17984.05	N/A
					Ω^-_{bbb}	12900.00	Unknown	32177.71	N/A

Table 2.7 - Accuracy of the Derived Mass Laws.

In this table, figures in red are the calculated values.

The accuracy of the two empirical mass laws derived here range from +3.815% to -3.183% for those particles with $J = 1/2\,\hbar$, and +1.329% to -2.374% for those particles with $J = 3/2\,\hbar$. This degree of accuracy is considered acceptable considering the uncertainty in the values of the quark masses as shown in Table 2.1.

3.0 Conclusions.

The six particles not used in the determination of the mass law for $J = 1/2\,\hbar$ Baryons, are low mass variants as shown in Table 2.2. This lower mass can be shown to be a due to a reduced level of quark confinement energy. There are four other particles in this category that were included in the determination of this mass law, because either one or both were previously recorded as of unknown mass. They are shown in the following table.

Particle	Quark Content	Recorded Mass	Calculated Mass	Variant	Recorded Mass	Calculated Mass
Λ_b^0	udb	5619.40	5731.82	Σ_b^0	unknown	5731.82
Ξ_{cb}^+	ucb	unknown	7487.11	$\Xi_{cb}^{/+}$	unknown	7487.11
Ξ_{cb}^0	dcb	unknown	7490.75	$\Xi_{cb}^{/0}$	unknown	7490.75
Ω_{cb}^0	scb	unknown	7638.11	$\Omega_{cb}^{/0}$	unknown	7638.11

Table 2.8 - Further $J = 1/2\,\hbar$ Particle Variants.

As a consequence of being included in the determination, the calculated mass of these particles and their variants are the same, whereas that of the particles in the first column should be slightly lower via reduced confinement energy as stated above. This anomaly can be corrected and will make a very small amendment to the mass law for particles with $J = 1/2\,\hbar$, which should accordingly provide a small improvement to its accuracy. It should be noted that this category of particles only appears to apply to those possessing three different quarks. The reason for this is not currently clear.

All Delta particles in the determination of the law for $J = 3/2\,\hbar$ particles have the same recorded mass. Because they all have a different quark content, their masses should be slightly different. This will obviously affect the accuracy of the calculated values. It is noted that there are several other less obvious examples of this discrepancy, all due to the factors affecting accuracy as detailed in Section 2.1.

While the plots of the Particle Mass vs Sum(Quark Mass), Figs. B.2 and C.2, provide a better visual representation of the relationship, any curve fit "laws" derived from them would not provide results as accurate as those derived from Figs. B1 and C.1. Such an exercise has not therefore been included.
Also, it should be noted that the actual curves shown in these plots are a visual aid only. The base axes values are not continuous variables but discrete values, and so only the individual points on each curve have a physical meaning.

Finally, the results here will subsequently enable the total energy of each particle to be apportioned into its constituent classes of (i) matter energy, the matter energy of the quark content, (ii) the energy associated with resonance levels, and (iii) the energy associated with quark confinement.

APPENDIX A

This appendix provides a detailed list of all sub-atomic Baryonic particles considered in this paper.

Item Number	Particle		Mass, (MeV/c^2)		Quark Content	Isospin	Charge	Baryon N°	Angular Momentum	Charm	Strange	Bottom	Life	Final Decay States	Branch Fraction
	Name	Symbol	Particle	Quark Content			*n*e`	B	J	C	S	B`	Secs		
1	Proton	p^+	938.27	9.55	uud	1/2	1	1	1/2+				Stable		
2	Neutron	n^0	939.57	11.90	udd	1/2	0	1	1/2+				887.5	$p^+ + e^- + (a)\nu_e$	100.000%
3	Lambda	Λ^0	1,115.68	107.15	uds	0	0	1	1/2+		-1		2.63E-10	$p^+ + \pi^-$	63.900%
4	Lambda	Λ^0	1,115.68		uds	0	0	1	1/2+		-1		2.63E-10	$n^0 + \pi^0$	35.800%
5	c Lambda	Λ^+_c	2,286.46	1,257.15	ucd	0	1	1	1/2+	1			2.00E-13	See PDG	See PDG
6	b Lambda	Λ^0_b	5,619.40	4,307.15	udb	0	0	1	1/2+			-1	1.43E-12	See PDG	See PDG
7	Sigma	Σ^+	1,189.37	104.80	uus	1	1	1	1/2+		-1		8.02E-11	$p^+ + \pi^0$	51.570%
8	Sigma	Σ^+	1,189.37		uus	1	1	1	1/2+		-1		8.02E-11	$n^0 + \pi^+$	48.310%
9	Sigma	Σ^0	1,192.64	107.15	uds	1	0	1	1/2+		-1		7.40E-20	$\Lambda^0 + \gamma$	100.000%
10	Sigma	Σ^-	1,197.45	109.50	dds	1	-1	1	1/2+		-1		1.48E-10	$n^0 + \pi^-$	99.848%
11	c Sigma	Σ^{++}_c	2,453.98	1,254.80	uuc	1	2	1	1/2+	1			2.91E-22	$\Lambda^+_c + \pi^+$	100.000%
12	c Sigma	Σ^+_c	2,452.90	1,257.15	ucd	1	1	1	1/2+	1			1.43E-22	$\Lambda^+_c + \pi^0$	100.000%
13	c Sigma	Σ^0_c	2,453.74	1,259.50	cdd	1	0	1	1/2+	1			3.05E-22	$\Lambda^+_c + \pi^-$	100.000%
14	b Sigma	Σ^+_b	5,811.30	4,304.80	uub	1	1	1	1/2+			-1	6.80E-23	$\Lambda^0_b + \pi^+$	100.000%
15	b Sigma	Σ^0_b	Unknown	4,307.15	udb	1	0	1	1/2+			-1	Unknown	Unknown	Unknown
16	b Sigma	Σ^-_b	5,815.50	4,309.50	ddb	1	-1	1	1/2+			-1	1.34E-22	$\Lambda^0_b + \pi^-$	100.000%
17	Xi	Ξ^0	1,314.86	202.40	uss	1/2	0	1	1/2+		-2		2.90E-10	$\Lambda^0 + \pi^0$	99.525%
18	Xi	Ξ^-	1,321.71	204.75	dss	1/2	-1	1	1/2+		-2		1.64E-10	$\Lambda^0 + \pi^-$	99.887%
19	c Xi	Ξ^+_c	2,467.80	1,352.40	ucs	1/2	1	1	1/2+	1	-1		4.42E-13	See PDG	See PDG
20	c Xi	Ξ^0_c	2,470.88	1,354.75	cds	1/2	0	1	1/2+	1	-1		1.12E-13	See PDG	See PDG
21	c Prime Xi	Ξ'^+_c	2,575.60	1,352.40	ucs	1/2	1	1	1/2+	1	-1		Unknown	$\Xi^+_c + \gamma$	Seen
22	c Prime Xi	Ξ'^0_c	2,577.90	1,354.75	cds	1/2	0	1	1/2+	1	-1		Unknown	$\Xi^0_c + \gamma$	Seen
23	cc Xi	Ξ^{++}_{cc}	Unknown	2,502.40	ucc	1/2	2	1	1/2+	2			Unknown	Unknown	Unknown
24	cc Xi	Ξ^+_{cc}	3,518.90	2,504.75	ccd	1/2	1	1	1/2+	2			3.30E-14	$\Lambda^+_c + K^- + \pi^+$	
25	cc Xi	Ξ^+_{cc}	3,518.90		ccd	1/2	1	1	1/2+	2			3.30E-14	$p^+ + D^+ + K^-$	
26	b Xi	Ξ^0_b	5,787.80	4,402.40	usb	1/2	0	1	1/2+		-1	-1	Unknown	See PDG	See PDG
27	b Xi	Ξ^-_b	5,791.10	4,404.75	dsb	1/2	-1	1	1/2+		-1	-1	1.56E-12	See PDG	See PDG
28	b Prime Xi	Ξ'^0_b	Unknown	4,402.40	usb	1/2	0	1	1/2+		-1	-1	Unknown	Unknown	Unknown
29	b Prime Xi	Ξ'^-_b	Unknown	4,404.75	dsb	1/2	-1	1	1/2+		-1	-1	Unknown	Unknown	Unknown
30	bb Xi	Ξ^0_{bb}	Unknown	8,602.40	ubb	1/2	0	1	1/2+			-2	Unknown	Unknown	Unknown
31	bb Xi	Ξ^-_{bb}	Unknown	8,604.74	dbb	1/2	-1	1	1/2+			-2	Unknown	Unknown	Unknown
32	cb Xi	Ξ^+_{cb}	Unknown	5,552.40	ucb	1/2	1	1	1/2+	1		-1	Unknown	Unknown	Unknown
33	cb Xi	Ξ^0_{cb}	Unknown	5,554.75	cdb	1/2	0	1	1/2+	1		-1	Unknown	Unknown	Unknown
34	cb Prime Xi	Ξ'^+_{cb}	Unknown	5,552.40	ucb	1/2	1	1	1/2+	1		-1	Unknown	Unknown	Unknown
35	cb Prime Xi	Ξ'^0_{cb}	Unknown	5,554.75	cdb	1/2	0	1	1/2+	1		-1	Unknown	Unknown	Unknown
36	c Omega	Ω^0_c	2,695.20	1,450.00	css	0	0	1	1/2+	1	-2		6.90E-14	See PDG	See PDG

Item Number	Particle		Mass, (MeV/c^2)		Quark Content	Isospin	Charge	Baryon N°	Angular Momentum	Charm	Strange	Bottom	Life	Final Decay States	Branch Fraction
	Name	Symbol	Particle	Quark Content			*n*e⁻	B	J	C	S	B`	Secs		
37	b Omega	Ω^-_b	6,071.00	4,500.00	ssb	0	-1	1	1/2+		-2	-1	1.13E-12	$\Omega^- + J/\psi$	Seen
38	cc Omega	Ω^+_{cc}	Unknown	2,600.00	ccs	0	1	1	1/2+	2	-1		Unknown	Unknown	Unknown
39	cb Omega	Ω^0_{cb}	Unknown	5,650.00	csb	0	0	1	1/2+	1		-1	Unknown	Unknown	Unknown
40	cb Prime Omega	$\Omega^{0/}_{cb}$	Unknown	5,650.00	csb	0	0	1	1/2+	1		-1	Unknown	Unknown	Unknown
41	bb Omega	Ω^-_{bb}	Unknown	8,700.00	sbb	0	-1	1	1/2+		-1	-2	Unknown	Unknown	Unknown
42	ccb Omega	Ω^+_{ccb}	Unknown	6,800.00	ccb	0	1	1	1/2+	2		-1	Unknown	Unknown	Unknown
43	cbb Omega	Ω^0_{cbb}	Unknown	9,850.00	cbb	0	0	1	1/2+	1		-2	Unknown	Unknown	Unknown
44	Delta	Δ^{++}	1,232.00	7.20	uuu	3/2+	2	1	3/2+				5.63E-24	$p^+ + \pi^+$	100.000%
45	Delta	Δ^+	1,232.00	9.55	uud	3/2+	1	1	3/2+				5.63E-24	$n^0 + \pi^+$	50.000%
46	Delta	Δ^+	1,232.00		uud	3/2+	1	1	3/2+				5.63E-24	$p^+ + \pi^0$	50.000%
47	Delta	Δ^0	1,232.00	11.90	udd	3/2+	0	1	3/2+				5.63E-24	$n^0 + \pi^0$	50.000%
48	Delta	Δ^0	1,232.00		udd	3/2+	0	1	3/2+				5.63E-24	$p^+ + \pi^-$	50.000%
49	Delta	Δ^-	1,232.00	14.25	ddd	3/2+	-1	1	3/2+				5.63E-24	$n^0 + \pi^-$	100.000%
50	* Sigma	Σ^{*+}	1,382.80	104.80	uus	1	1	1	3/2+		-1		1.84E-23	$\Lambda^0 + \pi^+$	87.000%
51	* Sigma	Σ^{*+}	1,382.80		uus	1	1	1	3/2+		-1		1.84E-23	$\Sigma^+ + \pi^0$	11.700%
52	* Sigma	Σ^{*+}	1,382.80		uus	1	1	1	3/2+		-1		1.84E-23	$\Sigma^0 + \pi^+$	
53	* Sigma	Σ^{*0}	1,383.70	107.15	uds	1	0	1	3/2+		-1		1.83E-23	$\Lambda^0 + \pi^0$	87.000%
54	* Sigma	Σ^{*0}	1,383.70		uds	1	0	1	3/2+		-1		1.83E-23	$\Sigma^+ + \pi^-$	11.700%
55	* Sigma	Σ^{*0}	1,383.70		uds	1	0	1	3/2+		-1		1.83E-23	$\Sigma^0 + \pi^0$	
56	* Sigma	Σ^{*-}	1,387.20	109.50	dds	1	-1	1	3/2+		-1		1.67E-23	$\Lambda^0 + \pi^-$	87.000%
57	* Sigma	Σ^{*-}	1,387.20		dds	1	-1	1	3/2+		-1		1.67E-23	$\Sigma^0 + \pi^-$	11.700%
58	* Sigma	Σ^{*-}	1,387.20		dds	1	-1	1	3/2+		-1		1.67E-23	$\Sigma^- + \pi^0$	
59	c * Sigma	Σ^{*++}_c	2,518.00	1,254.80	uuc	1	2	1	3/2+	1			4.42E-23	$\Lambda^+_c + \pi^+$	100.000%
60	c * Sigma	Σ^{*+}_c	2,517.50	1,257.15	ucd	1	1	1	3/2+	1			3.87E-23	$\Lambda^+_c + \pi^0$	100.000%
61	c * Sigma	Σ^{*0}_c	2,518.80	1,259.50	cdd	1	0	1	3/2+	1			4.54E-23	$\Lambda^+_c + \pi^-$	100.000%
62	b * Sigma	Σ^{*+}_b	5,832.10	4,304.80	uub	1	1	1	3/2+			-1	5.70E-23	$\Lambda^0_b + \pi^+$	100.000%
63	b * Sigma	Σ^{*0}_b	Unknown	4,307.15	udb	1	0	1	3/2+			-1	Unknown	Unknown	Unknown
64	b * Sigma	Σ^{*-}_b	5,835.10	4,309.50	ddb	1	-1	1	3/2+			-1	8.80E-23	$\Lambda^0_b + \pi^-$	100.000%
65	* Xi	Ξ^{*0}	1,531.80	202.40	uss	1/2	0	1	3/2+		-2		7.23E-23	$\Xi^0 + \pi^0$	100.000%
66	* Xi	Ξ^{*0}	1,531.80		uss	1/2	0	1	3/2+		-2		7.23E-23	$\Xi^- + \pi^+$	
67	* Xi	Ξ^{*-}	1,535.00	204.75	dss	1/2	-1	1	3/2+		-2		6.60E-23	$\Xi^0 + \pi^-$	100.000%
68	* Xi	Ξ^{*-}	1,535.00		dss	1/2	-1	1	3/2+		-2		6.60E-23	$\Xi^- + \pi^0$	
69	c * Xi	Ξ^{*+}_c	2,645.90	1,352.40	ucs	1/2	1	1	3/2+	1	-1		2.10E-22	$\Xi^0_c + \pi^+$	Seen
70	c * Xi	Ξ^{*0}_c	2,645.90	1,354.75	cds	1/2	1	1	3/2+	1	-1		2.10E-22	$\Xi^+_c + \pi^-$	Seen
71	cc * Xi	Ξ^{*++}_{cc}	Unknown	2,502.40	ucc	1/2	2	1	3/2+	2			Unknown	Unknown	Unknown
72	cc * Xi	Ξ^{*+}_{cc}	Unknown	2,504.75	ccd	1/2	1	1	3/2+	2			Unknown	Unknown	Unknown
73	b * Xi	Ξ^{*0}_b	5,945.50	4,402.40	usb	1/2	0	1	3/2+		-1	-1	3.10E-22	$\Xi^-_b + \pi^+$	Seen
74	b * Xi	Ξ^{*-}_b	Unknown	4,404.75	dsb	1/2	-1	1	3/2+		-1	-1	Unknown	Unknown	Unknown
75	bb* Xi	Ξ^{*0}_{bb}	Unknown	8,602.40	ubb	1/2	0	1	3/2+			-2	Unknown	Unknown	Unknown
76	bb* Xi	Ξ^{*-}_{bb}	Unknown	8,604.75	dbb	1/2	-1	1	3/2+			-2	Unknown	Unknown	Unknown
77	cb* Xi	Ξ^{*+}_{cb}	Unknown	5,552.40	ucb	1/2	1	1	3/2+	1		-1	Unknown	Unknown	Unknown

Item Number	Particle		Mass, (MeV/c^2)		Quark Content	Isospin	Charge	Baryon N^o	Angular Momentum	Charm	Strange	Bottom	Life	Final Decay States	Branch Fraction
	Name	Symbol	Particle	Quark Content			*n*e`	B	J	C	S	B`	Secs		
78	cb* Xi	Ξ^{*0}_{cb}	Unknown	5,554.75	cdb	1/2	0	1	3/2+	1		-1	Unknown	Unknown	Unknown
79	Omega	Ω^-	1,672.45	300.00	sss	0	-1	1	3/2+		-3		8.21E-11	$\Lambda^0 + K^-$	67.800%
80	Omega	Ω^-	1,672.45		sss	0	-1	1	3/2+		-3		8.21E-11	$\Xi^0 + \pi^-$	23.600%
81	Omega	Ω^-	1,672.45		sss	0	-1	1	3/2+		-3		8.21E-11	$\Xi^- + \pi^0$	8.600%
82	c Omega	Ω^{*0}_{c}	2,765.90	1,450.00	css	0	0	1	3/2+	1	-2		Unknown	$\Omega^0_{c} + \gamma$	100.000%
83	b Omega	Ω^{*-}_{b}	Unknown	4,500.00	ssb	0	-1	1	3/2+		-2	-1	Unknown	Unknown	Unknown
84	cc Omega	Ω^{*+}_{cc}	Unknown	2,600.00	ccs	0	1	1	3/2+	2	-1		Unknown	Unknown	Unknown
85	cb Omega	Ω^{*0}_{cb}	Unknown	5,650.00	csb	0	0	1	3/2+	1	-1	-1	Unknown	Unknown	Unknown
86	bb Omega	Ω^{*-}_{bb}	Unknown	8,700.00	sbb	0	-1	1	3/2+		-1	-1	Unknown	Unknown	Unknown
87	ccc Omega	Ω^{++}_{ccc}	Unknown	3,750.00	ccc	0	2	1	3/2+	3			Unknown	Unknown	Unknown
88	ccb Omega	Ω^{*+}_{ccb}	Unknown	6,800.00	ccb	0	1	1	3/2+	2		-1	Unknown	Unknown	Unknown
89	cbb Omega	Ω^{*0}_{cbb}	Unknown	9,850.00	cbb	0	0	1	3/2+	1		-2	Unknown	Unknown	Unknown
90	bbb Omega	Ω^{-}_{bbb}	Unknown	12,900.00	bbb	0	-1	1	3/2+			-3	Unknown	Unknown	Unknown

Table A.1 - Particles Considered with Full Details Where Known.

APPENDIX B

B.1 Empirical Mass Law for Particles with $J = 1/2\,\hbar$.

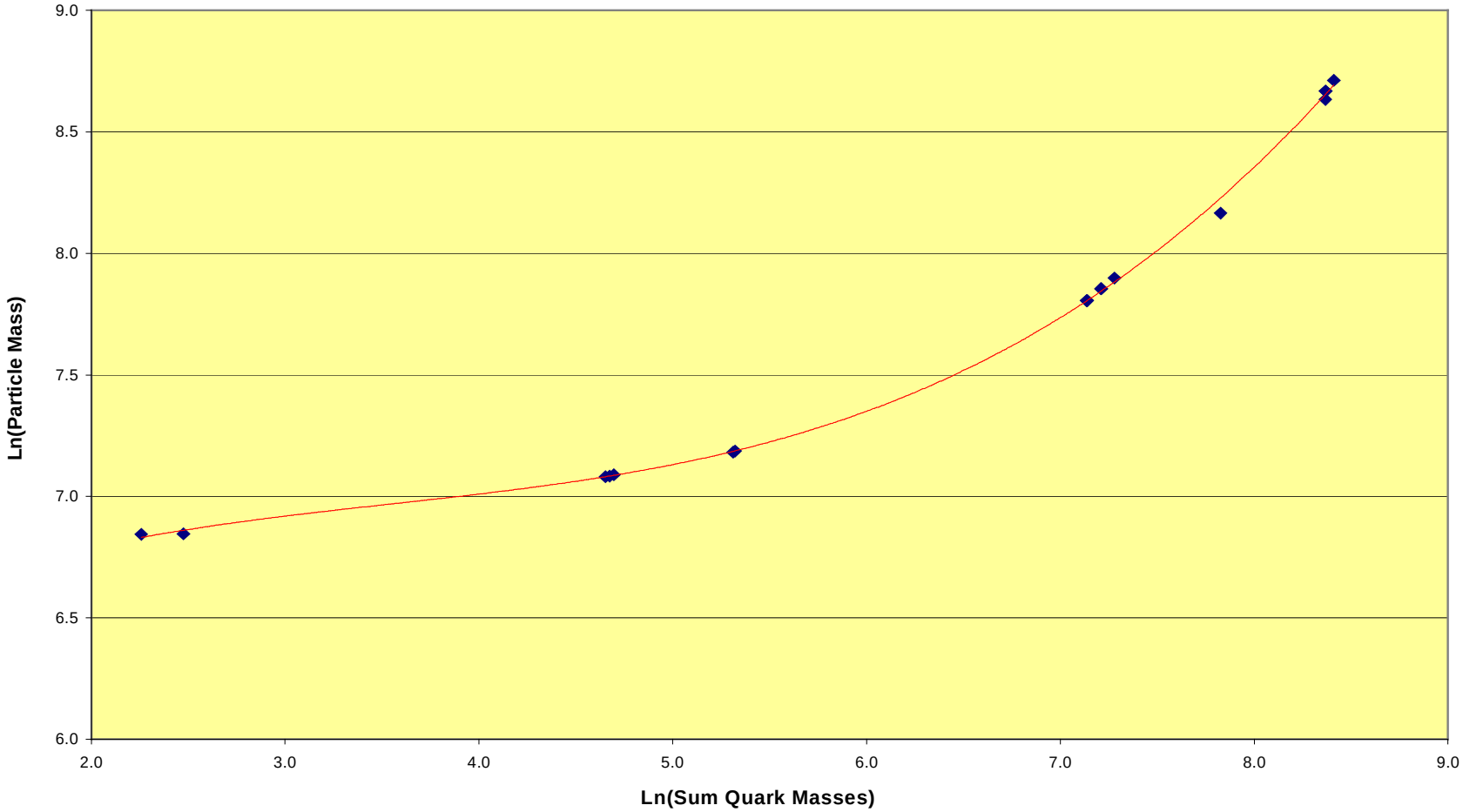

Fig.B.1 - Empirical Mass Law for Particles with $J = 1/2\,\hbar$.

B.2 Pictorial Mass Law Representation for Particles with $J = 1/2\,\hbar$.

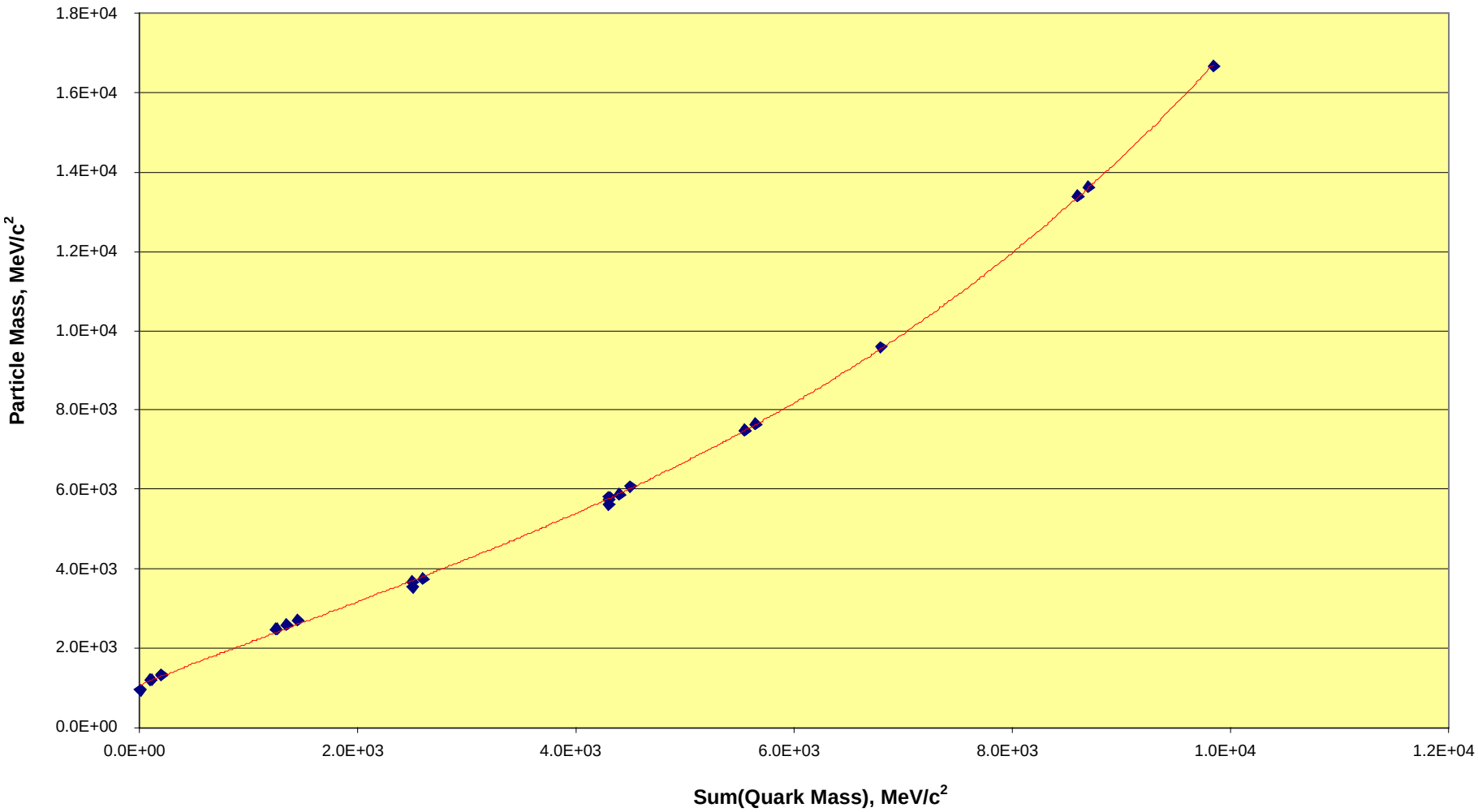

Fig.B.2 - Pictorial Mass Law Representation for Particles with $J = 1/2\,\hbar$.

APPENDIX C.

C.1 Empirical Mass Law for Particles with $J = 3/2\,\hbar$.

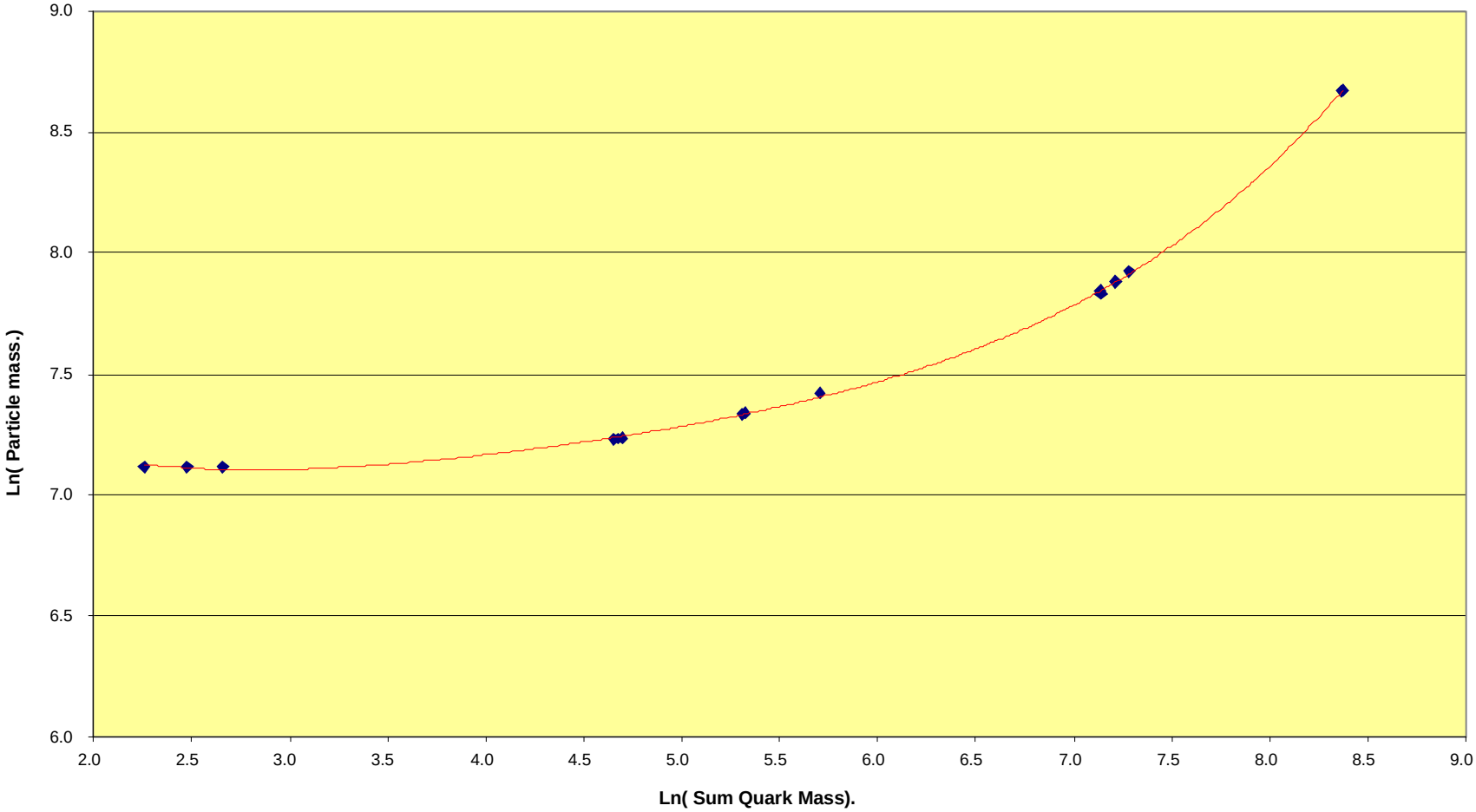

Fig.C.1 - Empirical Mass Law for Particles with $J = 3/2\,\hbar$.

C.2 Pictorial Mass Law Representation for Particles with $J = 3/2\,\hbar$.

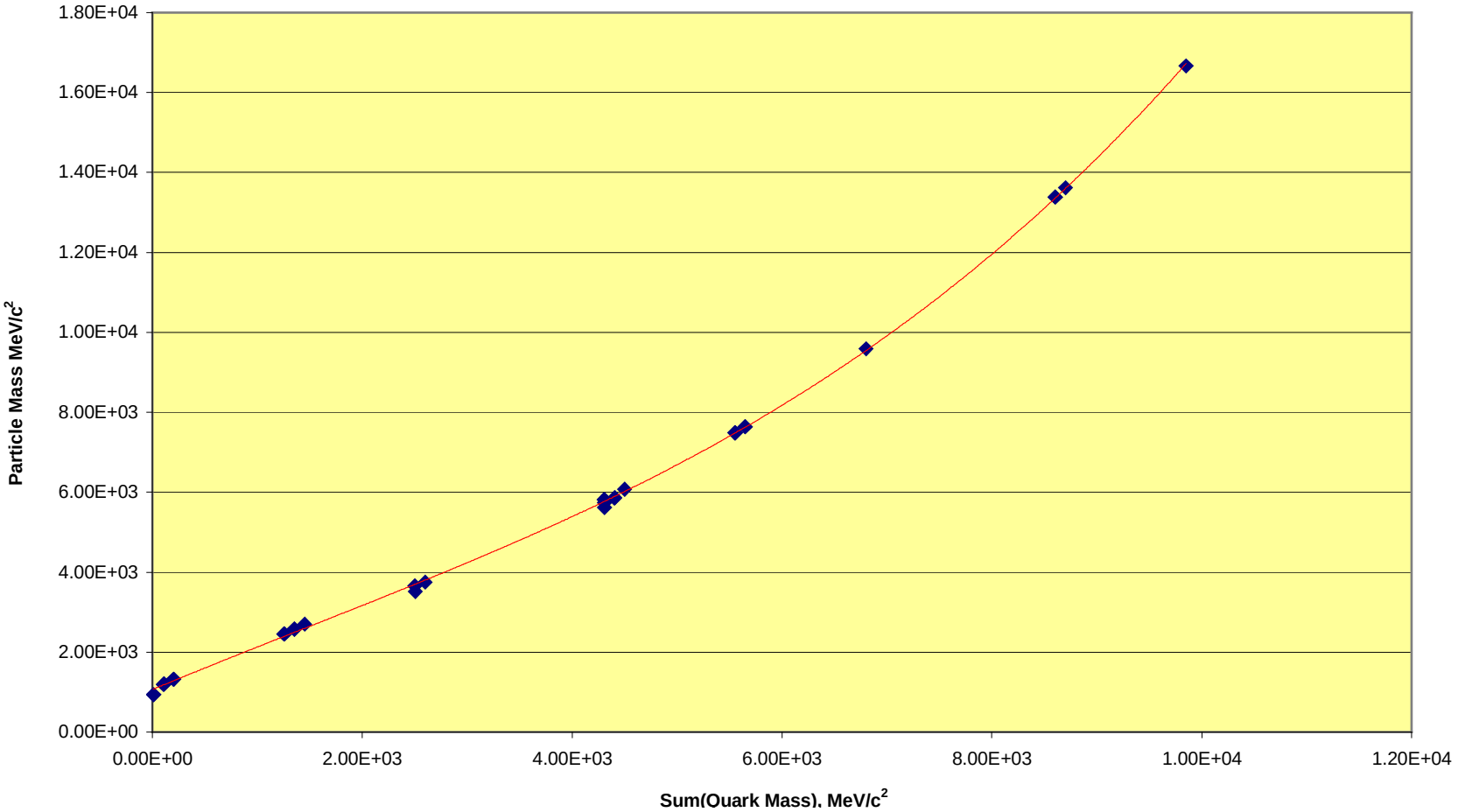

Fig.C.2 - Pictorial Mass Law Representation for Particles with $J = 3/2\,\hbar$.

REFERENCES.

[1] Wikipedia, *List of Baryons*, en.wikipedia.org.

[2] Particle Data Group, *Particle Listings*, pdg.lbl.gov.